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(54) **Titre** : PROCEDE ET TECHNIQUES POUR AMELIORER L'UNIFORMITE D'AFFICHAGE
(54) **Title:** METHODE AND TECHNIQUES FOR IMPROVING DISPLAY UNIFORMITY

(57) **Abrégé/Abstract:**

Disclosed is a implementation techniques to measure the aging, mismatches, and different information from a display.

ABSTRACT

Disclosed is a implementation techniques to measure the aging, mismatches, and different information from a display.

FIELD OF THE INVENTION

The present invention generally relates to improving the spatial and/or temporal non-uniformity of a display.

SUMMARY OF INVENTION

The disclosed techniques provide accurate measurement of the display temporal and spatial information and ways of applying this information to improve display uniformity.

ADVANTAGES

It can help improve the display uniformity and lifetime despite instability and non-uniformity of individual devices.

The disclosed outlines several techniques for extracting electrical characteristics data from a device under test (DUT). The device under test (DUT) can be any material (or device) including (but not limited to) LED, or OLED. This measurement can be effective in determining the aging (and/or uniformity) of an OLED in a panel . This extracted data can be stored in lookup tables as raw or processed data and can be used to compensate for any shift in the electrical parameters of the backplane (e.g. threshold voltage shift) or OLED (e.g. shift in the OLED operating voltage). Despite using OLED to explain the technology, it can be applied to any display technology including (but not limited to) OLED, LCD, or plasma. In the case of OLED, the electrical information measured can give an indication of any aging that may have occurred.

FIG. 1 shows a previous compensation technique where a voltage (Vout) is applied to the DUT, and the resulting current is compared to a reference current. The voltage can be adjusted until the devices current equals the reference current, or alternatively, the reference current can be adjusted until it equals the device's current.

FIG.2 shows a method similar to FIG. 1, except a second reference current is used as a "carrier" current. One possible driving scheme for this method is to keep V_{OUT} and Ref_Current_1 constant and vary Ref_Current_2 until the two currents into the current comparator match. Since the reference currents are known, the DUT's current can be determined by I_{DUT} = **Ref_Current_2 - Ref_Current_1**

Figure 3 shows a method of applying a current to the DUT and measuring the voltage. In this case, the voltage is measured with a Analog to Digital Converter (ADC). A higher voltage is necessary for a device such as an OLED ages is higher compared to a new OLED. This method gives a direct measurement of that voltage change.

Current flow can be in any direction. In the above examples, it is shown going into the device under test (DUT) for illustration purposes.

The backplane for driving the display can be any technology including (but not limited to) amorphous silicon, poly silicon, crystalline silicon, organic semiconductors, oxide semiconductors. Also, the emission block can be any material (or device) including (but not limited to) LED, or OLED. Also, despite using OLED to explain the technology, it can be applied to any display technology including (but not limited to) OLED, LCD, or plasma.

In a display system (FIG. 4) which measures sub-pixels, reference pixels help correct or normalize the data collected during measurement. Reference pixels may be located outside the active viewing (FIG.5), may also be embedded within the active viewing areas. These reference pixels are un-aged, or aged in a predetermined fashion to provide offset and cancellation information for measurement data of the displaying sub-pixels. This information helps cancel out common mode noise from external sources, e.g. room temperature, or within the system itself, e.g. leakage currents from other sub-pixels. Using a weighted average from several pixels on the panel can also provide information on panel-wide characteristics to address problems such as voltage drops due to the resistance across the panel, i.e. IR drop. Information from the reference pixels being stressed by a known and controlled source can be used in the compensation algorithm to reduce compensation errors occurring from any divergence. Reference pixels may be selected using the data collected from the initial baseline measurement of the panel. Bad reference pixels are identified, and alternate reference pixels may be chosen.

There are various methods that can make use of the reference pixel. For example in TFT measurement, the data value required for the reference sub-pixel to output a current is subtracted from the data value of a sub-pixel in the active area to output the same current. The measurement of both pixels may occur very close in time, e.g. during the same video frame. Another use of a reference sub-pixel would be to use it as the reference current of the other sub-pixels. This method may simplify the data manipulation since some of the common mode noise cancellation is inherent in the measurement.

Here, the current comparator can be any technology including (but not limited to) CMOS semiconductor. Figure 6 shows an example of a CMOS current comparator circuit. Here, the values for V_{B1} and V_{B2} must be determined for a given I_{ref}. The voltage inputs to the comparator (V_{B1} and V_{B2}) can be controlled using Digitial to Analog Converter (DAC) devices. Level shifters can also be added if the voltage range of the DAC isn't sufficient. See Figure 7. The current can originate from a voltage controlled current source such as an op-amp circuit or even just a transistor, e.g. TFT. The example shown here is using an op-amp circuit such as the one shown in Figure 8.

To find the optimal voltage biasing, one of the voltages is fixed, e.g. V_{b1}, while the other voltage sweeps through a range of voltages. Figure 9 shows the signaling for creating a series of comparator results that are alternating “High” and “Low”. “CAL” signals when to measure the first current and and “EN” signals when to measure the second current and output the result of the comparison. Several iterations of alternating the high and low currents are done at each voltage. A voltage can be selected based on the largest continuous series of alternating comparator results.

A measurement of all TFTs and OLEDs before shipping displays will take 60-120 seconds for a 1080p display, and will detect any shorted and open TFTs and OLEDs (which result in stuck or unlit pixels). It will also detect non-uniformities in TFT or OLED performance (which result in luminance non-uniformities). This technology can replace optical inspection by a digital camera, removing the need for this expensive component in the production facility. AMOLEDs that use color filters cannot be fully inspected electrically, since color filters are a purely optical component. In this case, the MaxLife™ technology can still be useful in combination with an optical inspection step, by providing extra diagnostic information and potentially reducing the complexity of optical inspection.

However a more significant advantage is that these measurements contain more data than optical inspection can provide. Knowing whether a point defect is due to a short or open TFT, or a short or open OLED can help to identify the root cause. For example, the most common cause for a short circuit OLED is particulate contamination that lands on the glass during processing, shorting anode and cathode. An increase in OLED shorts could indicate that the line should be shut down for chamber cleaning, or searches could be initiated for new sources of particles (changes in processes, or equipment, or personnel, or materials).

MaxLife™ can correct for process non-uniformities, which increases yield. However the measured IV characteristics (the relationship between current and voltage) in the TFT or OLED are useful for diagnostics as well. For example, the shape of an OLED IV characteristic can reveal increased resistance. A likely cause might be variations in the contact resistance between the TFT source/drain metal and the ITO (in a bottom emission AMOLED). If OLEDs in a corner of a display showed a different IV characteristic, a likely cause could be mask misalignment.

A streak or circular area on the display with different OLED IV characteristics could be due to defects in the manifolds used to disperse the organic vapor. In one possible scenario, a small particle of OLED flakes from an overhead shield and lands on the manifold, partially obstructing the orifice. The measurement data would show the differing OLED IV in a specific pattern which would help to quickly diagnose the issue. Due to the accuracy of the measurements (the 4.8" display measures current with a resolution of 0.1nA), and the measurement of the OLED IV itself (instead of the luminance), variations can be detected that are not visible with optical inspection.

This high-accuracy data can be used for statistical process control, identifying when a process has started to drift outside of its control limits. This can allow corrective action to be taken early (in either the OLED or TFT process), before defects are detected in the finished product. The measurement sample is maximized since every TFT and OLED on every display is sampled.

If the TFT and OLED are both functioning properly, a reading in the expected range will be returned. The pixel circuit requires that the OLED be off when the TFT is measured (and vice-versa), so if the TFT or OLED is a short circuit, it will obscure the measurement of the other. If the OLED is a short circuit (so the current reading is MAX), the data will show the TFT is an open circuit (current reading MIN) – in reality, the TFT could be OK or an open circuit. If extra data about the TFT is needed, temporarily disconnecting EL_VSS and allowing it to float will yield a correct TFT measurement.

In the same way, if the TFT is a short circuit, the data will show the OLED is an open circuit (but it could be OK, or an open circuit). If extra data about the OLED is needed, disconnecting EL_VDD and allowing it to float will yield a correct OLED measurement.

If both the OLED and TFT in a pixel behave as a short circuit, one of the elements in the pixel (likely the contact between TFT and OLED) will quickly burn out during the measurement, causing an open circuit, and moving to a different state. These results are summarized in **Error! Reference source not found.**.

Figure 10 shows a system diagram for controlling the brightness of the display over time based on different aspects. Here, to improve the power consumption, display lifetime, and image quality, different brightness profile can be defined based on OLED and backplane information. Also, based on different applications, one can select different profiles. For example, a flat brightness vs. time profile can be used for movies whereas for more bright applications, the brightness can be drop at a defined rate.

To compensate for display aging perfectly, we need to separate the short term and long term changes in the display characteristics. One way, is to measure few point across the display with faster past. As a result, the fast scan can reveal the short term effects while the normal aging extraction can reveal the long term effects.

The previous implementation of the MaxLife system used a normal driving scheme, in which there was always a video frame shown on the panel and the OLED and TFT circuitries were constantly under electrical stress. Moreover, pixel calibration (data replacement and measurement) of each sub-pixel occurred during video frame by changing the grayscale value of the active sub-pixel to a desired value. This would cause visual artifact of seeing the measured sub-pixel during the calibration. It could also worsen the aging of the measured sub-pixel, since the modified grayscale was kept on the sub-pixel for duration of the entire frame.

With the newly developed relaxation scheme both the video driving and calibration schemes are improved as described below.

If the frame rate of the video is X, then in normal video driving, each video frame is shown on the panel for 1/X of second and the panel is always running a video frame.

```
|---------------------------------------------------------------------------------------------------|
|                                          Video frame                                              |
|---------------------------------------------------------------------------------------------------|
<---------------------------------------------- X ms ----------------------------------------------->
```

Normal video driving

The relaxation video driving divides the frame time into four sub-frames as shown below.

```
<---------- a.X ms ----------> <----------- b.X ms ----------> <----------- c.X ms ----------><--- d.X ms --->
|------------------------------|-------------------------------|------------------------------|-----------------|
|   Video sub-frame            |     Dummy sub-frame           |  Relaxation sub-frame        | Replacement     |
|------------------------------|-------------------------------|------------------------------|-----------------|
<----------------------------------------------------- X ms ---------------------------------------------------->
```

Relaxation video driving

a+b+c+d = 1

1. **Video sub-frame:** The first sub-frame is the actual video frame, which is generated the same way as normal video driving to program the entire panel with the video data received from input.
2. **Dummy sub-frame:** The dummy sub-frame is an empty sub-frame without any actual data being sent to the panel. This is just to keep the same video frame displayed on the panel for some time before applying the relaxation sub-frame. This helps to increase the luminance of the panel.
3. **Relaxation sub-frame:** The third sub-frame is the relaxation sub-frame, which is a black frame with zero grayscale value for all of the RGBW sub-pixels. This makes the panel black and sets all the sub-pixel to a predefined state ready for calibration and next video sub-frame insertion.

4. **Replacement sub-frame:** This sub-frame is a short sub-frame generated solely for the purpose of calibration. When the relaxation sub-frame is done and the panel is black the data replacement phase starts. No video or blank data is sent to the panel during this phase except for the rows with replacement data. For the non-replacement rows only the gate driver's clock is toggled to shift the token throughout the gate driver. This is done to speed up the scanning of the entire panel and also to be able to do more measurement per each frame.

Another technique is used to further alleviate the visual artifact of the measured sub-pixel during the replacement sub-frame. This has been done by re-programming the measured row with black as soon as the calibration is done. This returns the sub-pixel to the same state as it was during the Relaxation sub-frame. However, there is still a small current going through OLED, which makes it light up and noticeable to the outside world. Therefore to re-direct the current going though OLED, the MONITOR is programmed with a non-zero value to sink the current from the TFT and keep the OLED off.

Baseline measurement

Having a replacement sub-frame has a drawback of limiting the time of the measurement to a small portion of the entire frame. This limits the number of sub-pixel measurements per each frame. This limitation is acceptable during the working time of the TV. However, for a quick baseline measurement of the panel it would be a time-consuming task to measure the entire display. To overcome this issue a baseline mode was added to the relaxation driving scheme. If the system is switched to baseline mode, the driving scheme changes such that there would only be two sub-frames. One is the video sub-frame and the other is the replacement (measurement sub-frame). This will drastically increase the total number of measurements per each frame. The following figure shows the driving scheme during the baseline measurement.

```
<---------- a.X ms ----------> <---------------------------------- e.X ms -------------------------------------->
|-------------------------------------------------------------------------------------------------------------|
|    Video sub-frame      |                Replacement sub-frame                                             |
|-------------------------------------------------------------------------------------------------------------|
<------------------------------------------------------ X ms ------------------------------------------------------>
```

Baseline driving scheme

TABLE 1

		OLED		
		Short	OK	Open
TFT	Short	n/a	TFT MAX OLED MIN	TFT MAX OLED MIN
	OK	TFT MIN OLED MAX	TFT OK OLED OK	TFT OK OLED MIN
	Open	TFT MIN OLED MAX	TFT MIN OLED OK	TFT MIN OLED MIN

Float EL_VDD
to distinguish

Float EL_VDD
to distinguish

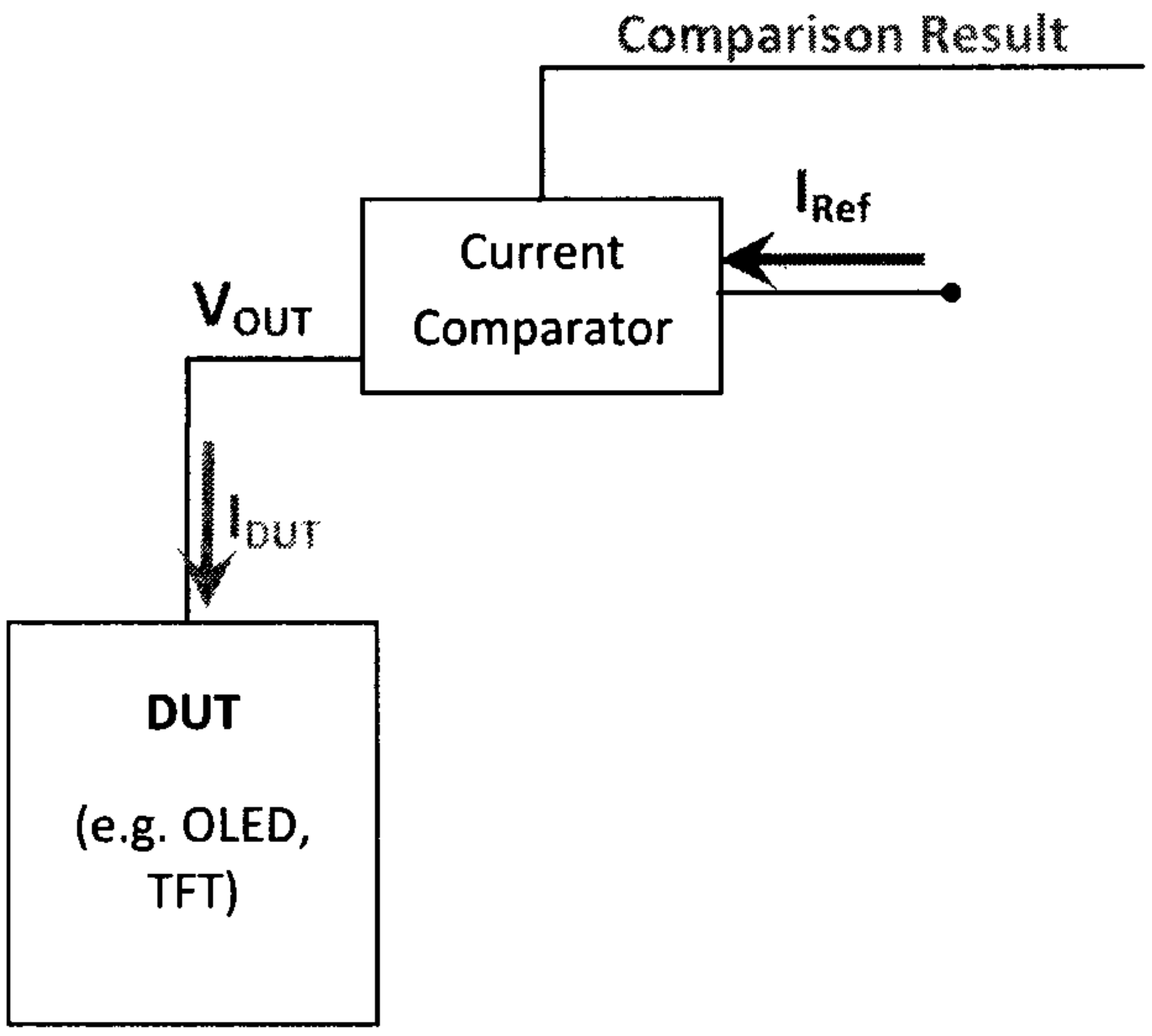

FIG. 1: Current Calibration Method 1

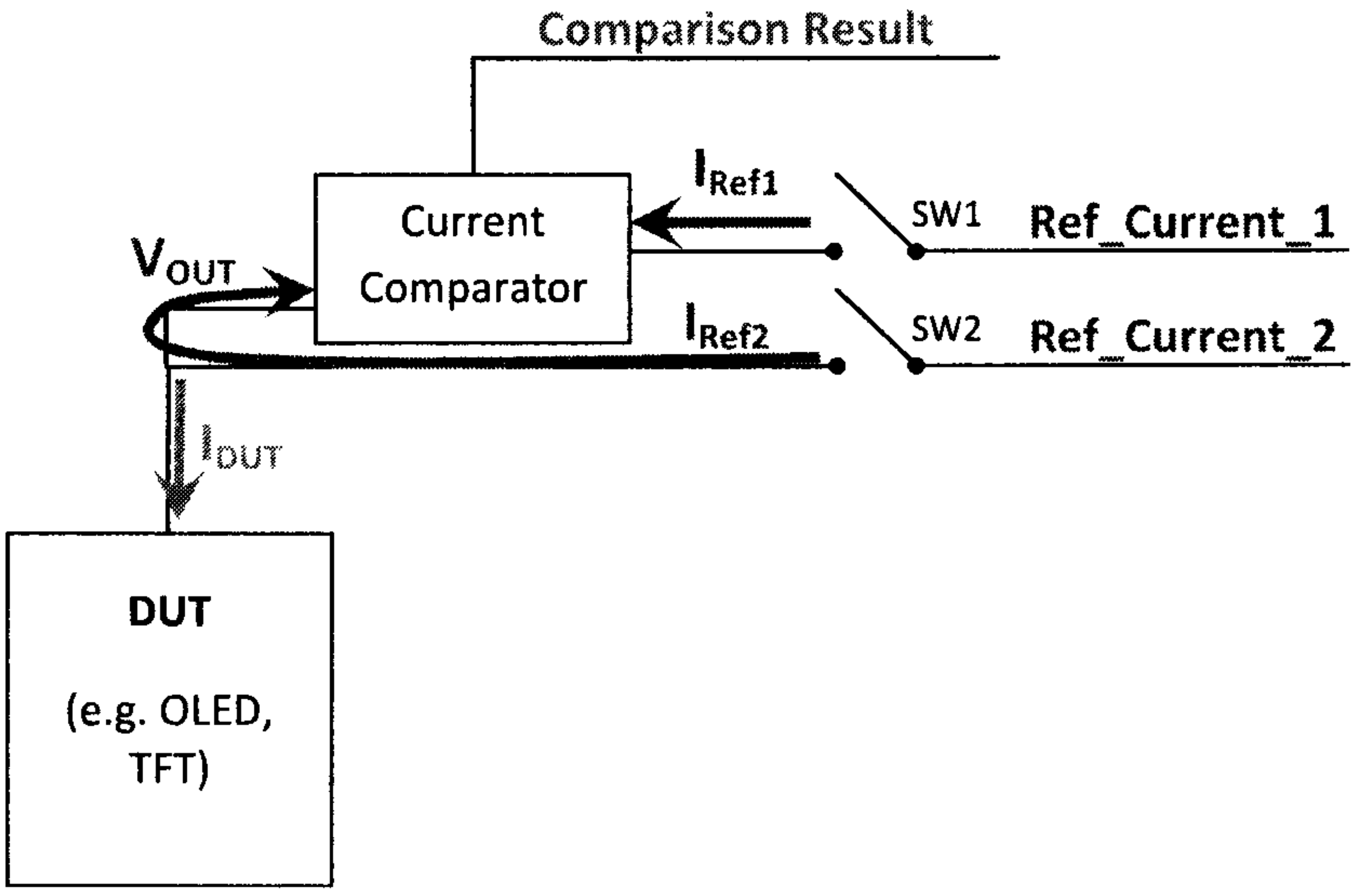

FIG2: Current Calibration Method 2

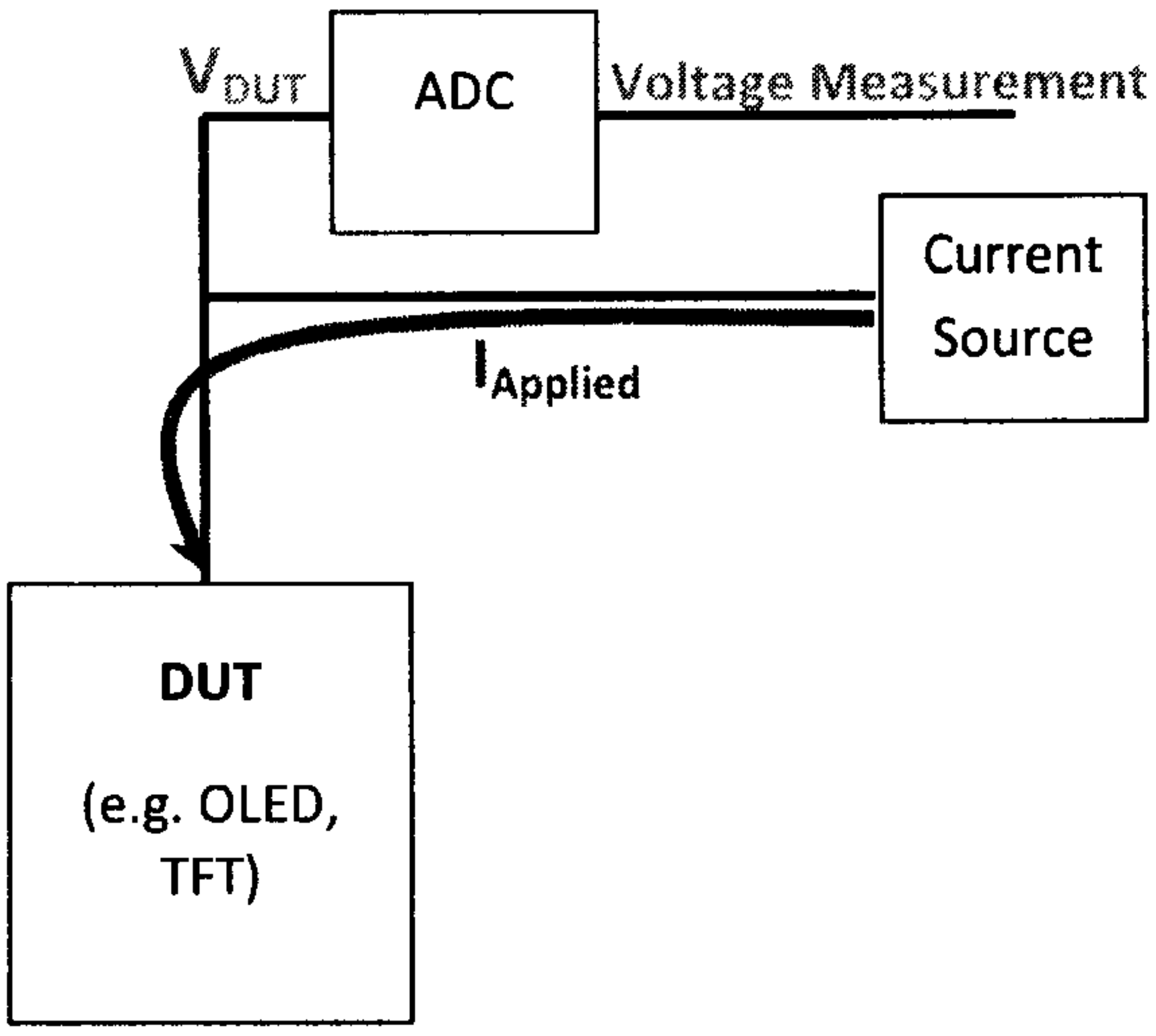

FIG 3: Voltage Calibration

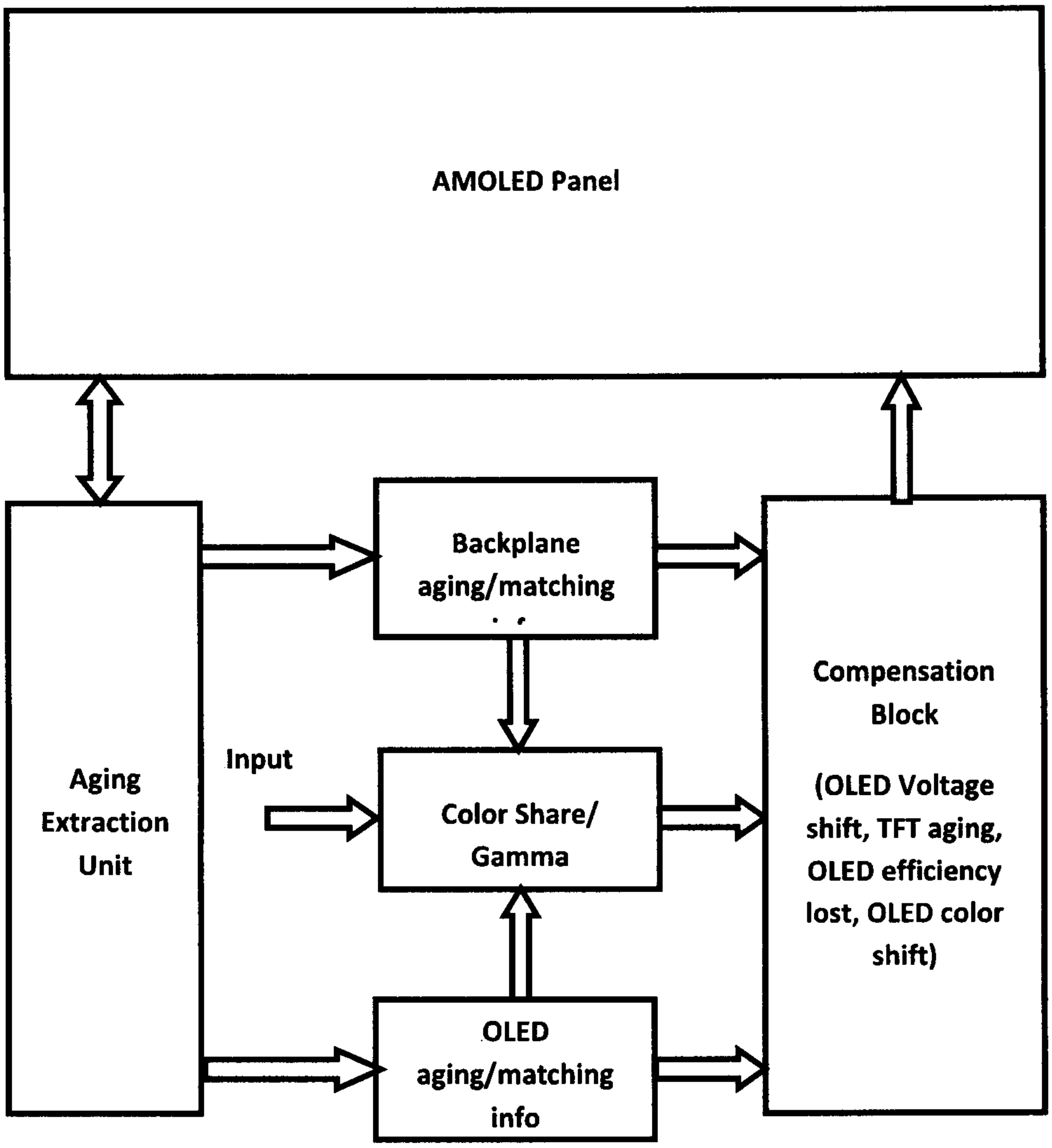

FIG 4: Sub-Pixel OLED Compensation System

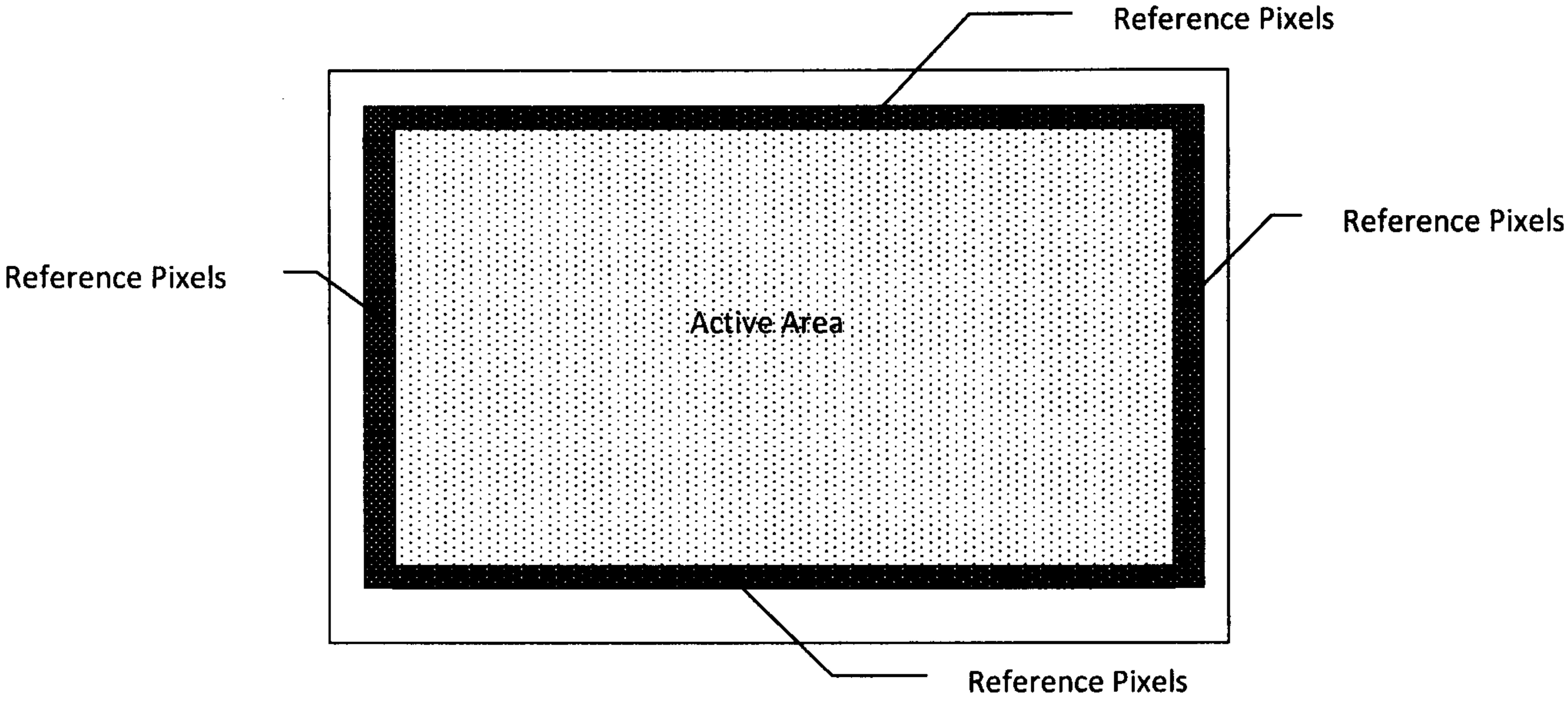

FIG 5: Example of reference pixel locations

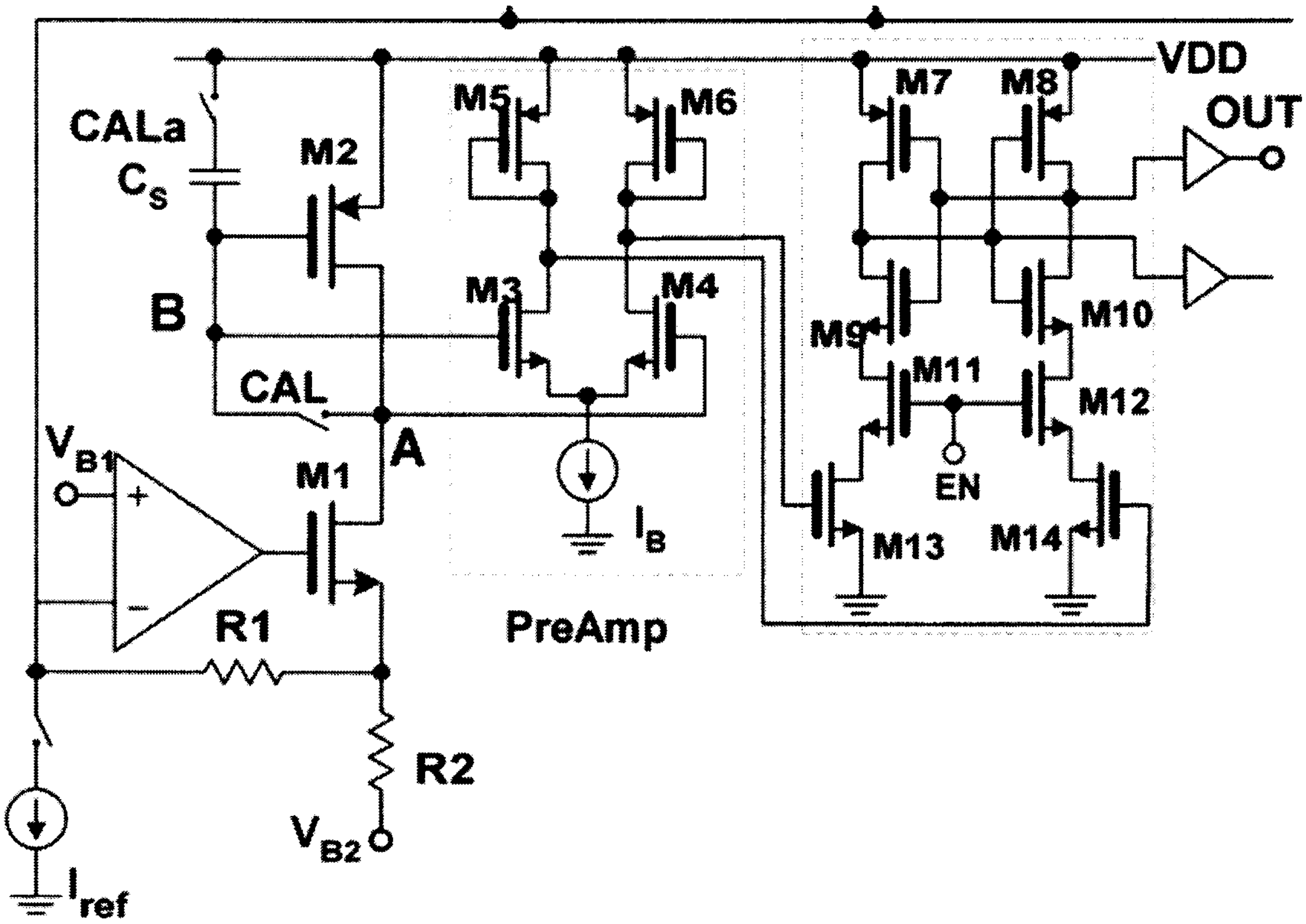

FIG. 6: Current Comparator Circuit

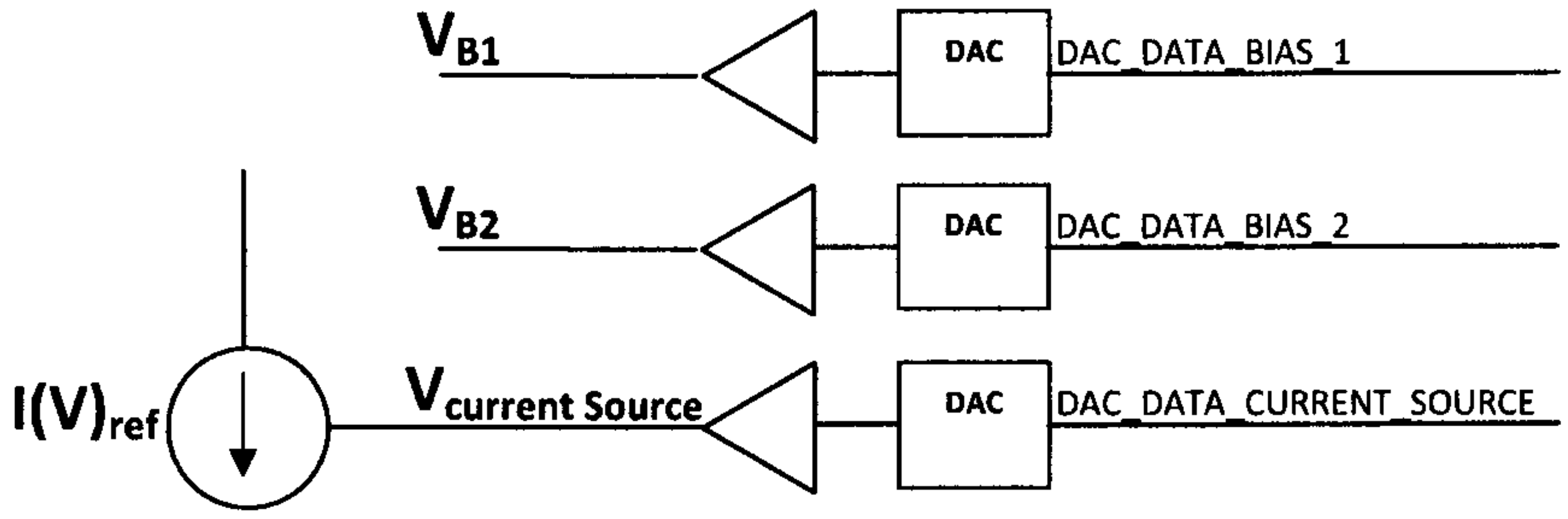

FIG7: Voltage Biasing Control

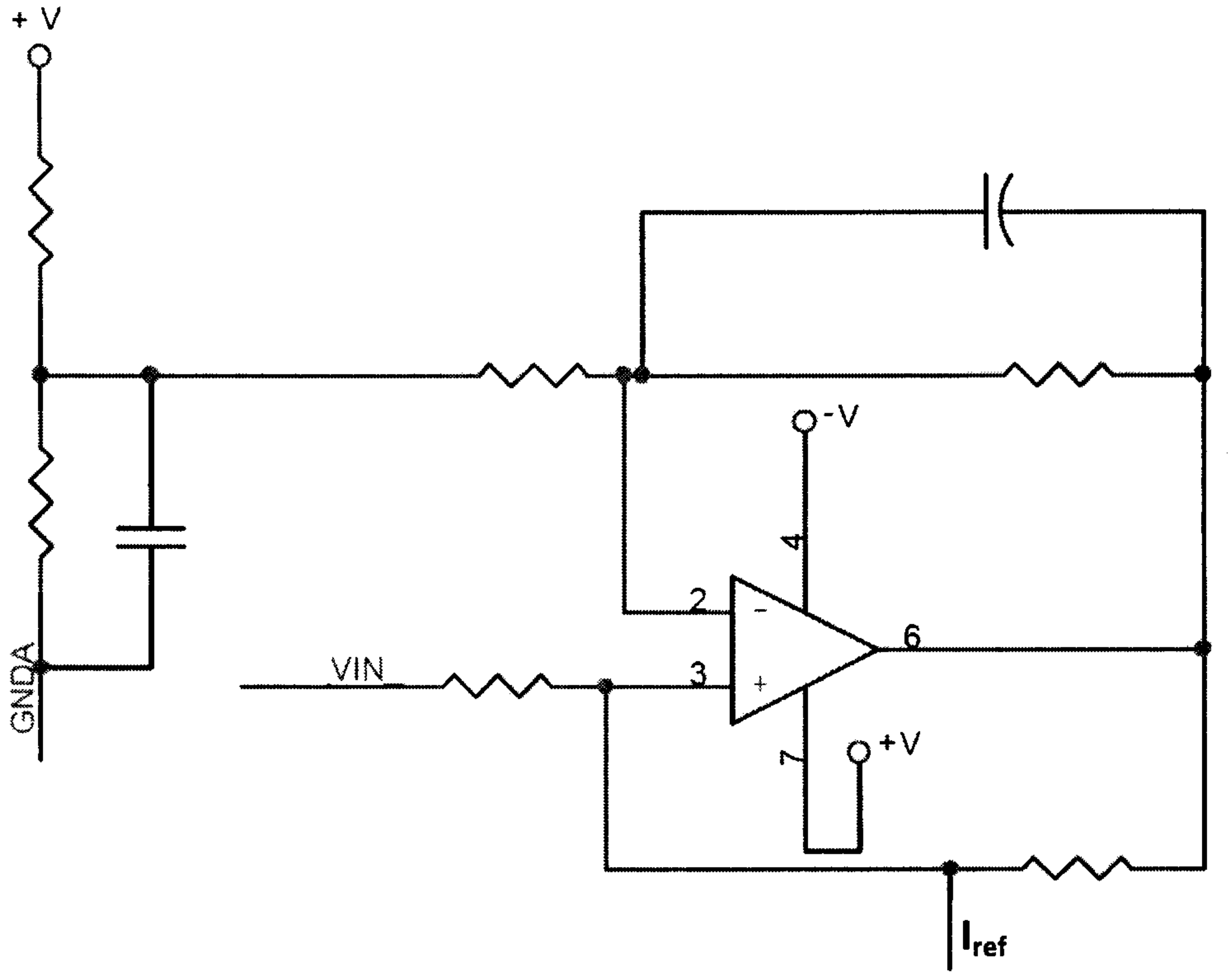

FIG 8: Sample Current Bias Circuit

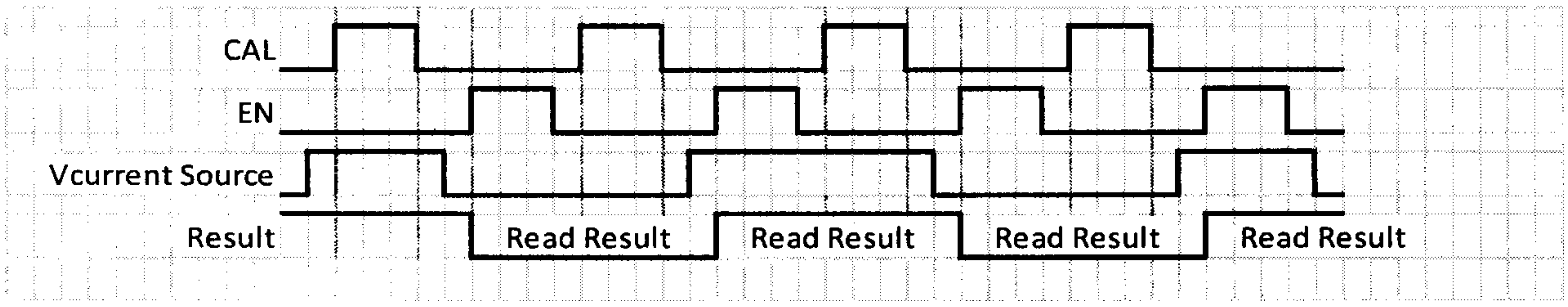

FIG 9: Drive Scheme for Alternating Results pattern of “Higher” and “Lower”

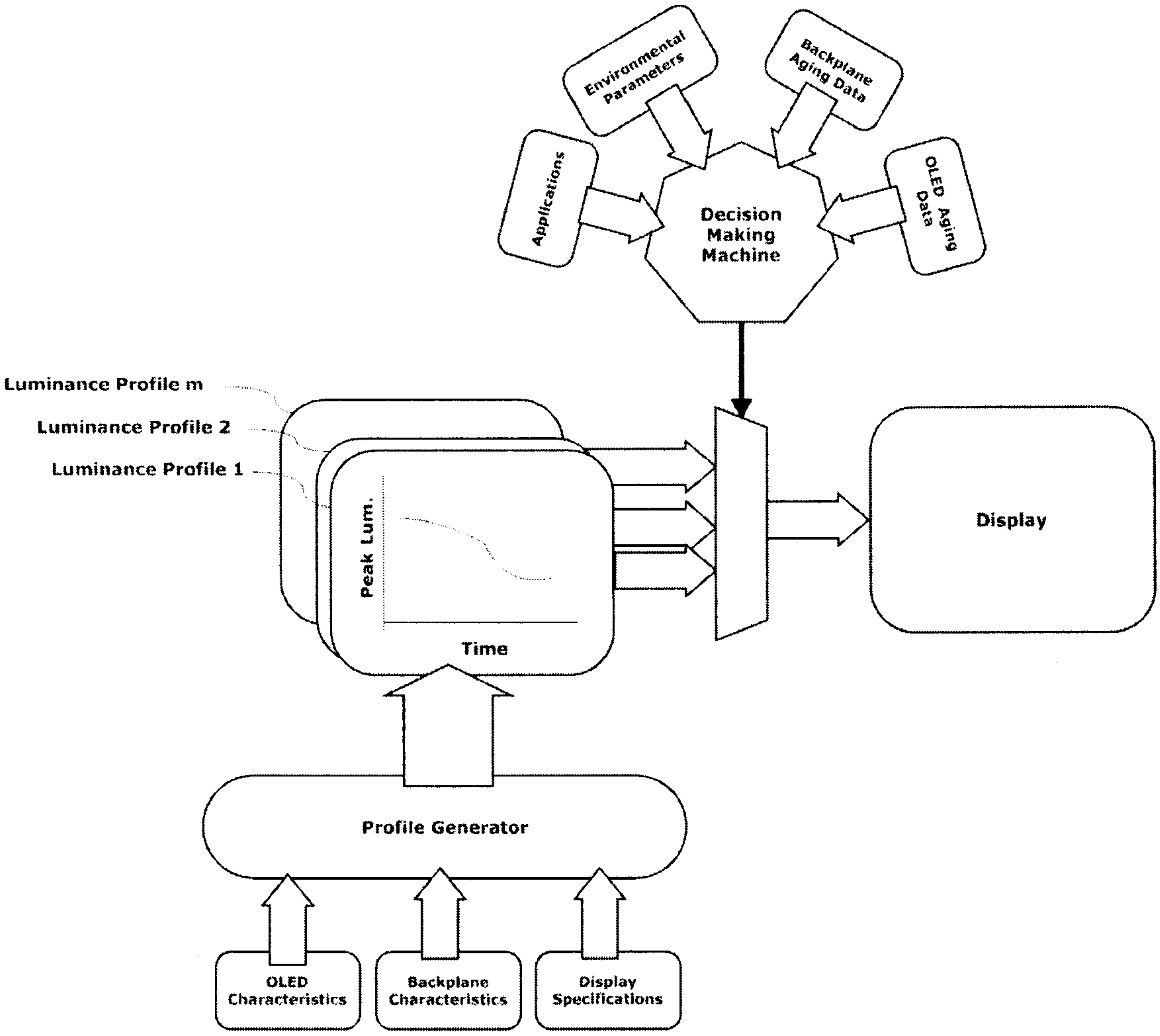
Environmental Parameters
Backplane Aging Data
Applications
Decision Making Machine
OLED Aging Data
Luminance Profile m
Luminance Profile 2
Luminance Profile 1
Peak Lum.
Time
Display
Profile Generator
OLED Characteristics
Backplane Characteristics
Display Specifications

FIG 10